SUMMARY REPORT – FORMER MGP OPERATIONS AND DENSE NON-AQUEOUS PHASE LIQUID OCCURRENCE

NW Natural – Gasco Property
7900 NW St. Helens Road
Portland, Oregon

and

Siltronic Corporation Property
7200 NW Front Avenue
Portland, Oregon

November 7, 2005

Project No. 2708

SUMMARY REPORT – FORMER MGP OPERATIONS AND DENSE NON-AQUEOUS PHASE LIQUID OCCURRENCE

NW Natural – Gasco Property
7900 NW St. Helens Road
Portland, Oregon

and

Siltronic Corporation Property
7200 NW Front Avenue
Portland, Oregon

November 7, 2005

Prepared for:

NW Natural
Portland, Oregon

Prepared by:

Hahn and Associates, Inc.
Portland, Oregon

HAI Project No. 2708

TABLE OF CONTENTS

Table of Contents
(continued)

TABLES

Table of Contents
(continued)

FIGURES

APPENDICES

1.0 EXECUTIVE SUMMARY

This document has been prepared to describe the known distribution of dense non-aqueous phase liquid (DNAPL) related to historical management of manufactured gas plant (MGP) wastes at the NW Natural Gasco and the adjacent Siltronic Corporation (Siltronic) properties, located in Portland, Oregon. This report includes a summary of historical operations, contaminant sources, and hydrogeological conditions to support an overall evaluation of whether MGP-related DNAPL present in upland portions of the properties may be a current or potential future source of DNAPL impact to sediments within the Willamette River.

DNAPL is a separate phase hydrocarbon liquid that is denser than water. DNAPL will occur in the subsurface as either a free-phase or residual liquid. Residual DNAPL is trapped by capillary pressure and is immobile. Free-phase DNAPL will either have the ability to migrate, or it may be immobilized due to the presence of down-dip (underlying or adjacent) impermeable barriers (e.g., be stratigraphically trapped).

DNAPL, both as immobile residual liquid, and in more limited areas, as free-phase liquid, has been identified at both the Gasco and Siltronic properties. Sources for the DNAPL at Gasco are attributable to leaks and spills from former MGP process areas as well as from discharge of oily effluent to former waste management areas and incorporation into fill. At Siltronic, the presence of DNAPL attributable to MGP-related activities is limited to waste management sources on the northern portion of the property where effluent pond overflow and tar placement activities were previously conducted between 1941 and 1956.

1.1 Gasco Property

At the Gasco property, areas of free-phase DNAPL occurrence exist within the surficial fill water-bearing zone (WBZ) beneath and down-dip (relative to the underlying native silt unit) of the former MGP operational areas (primarily south to southwestern property well away from the river), and within the alluvial WBZ beneath the former effluent discharge area and the former effluent tar pond area (eastern portion of the property, proximate to the river). Other areas of DNAPL occurrence exist at the property, all within the fill, but the occurrences are limited, patchy, and appear to be residual (immobile).

1.1.1 Former Process Areas

DNAPL identified beneath the former MGP process areas has been delineated laterally and vertically and is stratigraphically trapped by the underlying silt unit. No DNAPL or significant dissolved phase impacts have been identified within the alluvial WBZ beneath, or immediately down-gradient from, these locations. DNAPL from these areas does not have a complete migration pathway to the Willamette River.

1.1.2 Former Effluent Discharge Area

DNAPL beneath the former effluent discharge area is present as free-phase, potentially mobile product identified across a depth interval of approximately 27.5 to 44 feet below ground surface (bgs). This DNAPL was discharged to the former ground surface (beneath the present fill) in this area. The lateral and vertical extent of DNAPL occurrence in this area has been delineated, as has the lateral and vertical extent of dissolved phase impact within groundwater. Borings installed off-shore of the upland DNAPL occurrence depict a thickening wedge of silt that appears to have prevented DNAPL migration from the upland area to the river.

Migration of DNAPL from the upland area to the river has not been identified. However, as a precaution, due to the lateral and vertical proximity of the free-phase DNAPL to the base of the river, an evaluation of remedial measures is presently being conducted for this area to ensure the potential for future migration to the river is minimized.

1.1.3 Former Tar Effluent Pond Area

DNAPL related to the former tar effluent ponds is present below the eastern corner of the property, as a function of oil and oil/water emulsions discharged with tar to this area and oily emulsions derived from tars placed in this area. DNAPL has been observed within thin rootlet casts in the native silt unit beneath the former effluent ponds, with DNAPL penetration into a limited area of the alluvial WBZ beneath the former pond area, with a maximum observed penetration depth of 67 feet bgs. The DNAPL penetration into the alluvial WBZ has resulted in a well defined (laterally and vertically) dissolved phase plume beneath and extending down-gradient from this area.

Free-phase DNAPL has been observed within the alluvial WBZ across a depth interval of approximately 58 to 59 feet bgs in one nearshore well (PW-1-80) located proximate to the former tar effluent pond area, between the former pond area and the river. This DNAPL appears present as a function of lateral migration from below the former tar pond area. DNAPL has not been observed at nearby locations, including a well cluster installed between PW-1-80 and the river, and therefore appears quite limited.

Collection of additional data off-shore of the PW-1-80 location is being proposed to ascertain the potential for migration of DNAPL or dissolved phase impact from this upland location to river sediments.

1.2 Siltronic Property

Petroleum-related DNAPL and solid to semi-solid tar are present in the subsurface at the Siltronic site, with DNAPL present both within the surficial fill WBZ, and in a more isolated area (extreme northern portion of the property), within the underlying alluvial WBZ.

DNAPL related to former MGP-related waste management activities at Siltronic is restricted to a former lowland area where tar was placed or tar and oily effluent overflowed from the tar pond effluent area at the adjacent Gasco property. Other areas of NAPL occurrence exist at the property (all within the fill), but the occurrences are limited, patchy, and appear to be residual (immobile).

1.2.1 *Former Lowland Area-Surficial Fill WBZ*

Free-phase DNAPL has been identified within the surficial fill WBZ at the north-central portion of the former lowland portion of the site (well WS-10-27). The DNAPL identified at this portion of the site has been delineated laterally in all directions except to the east-southeast (below the Fab 2 structure) and toward the western corner of the property. The DNAPL at this location has been completely delineated vertically. Similar to the southern portion of the Gasco property, this DNAPL is stratigraphically trapped by the underlying native silt unit and does not have a complete migration pathway to the Willamette River.

1.2.2 *Former Lowland Area-Alluvial WBZ*

DNAPL within the alluvial WBZ at Siltronic is limited to the northern corner of the property at a location proximate to the western end of the Fab 1 structure, where DNAPL has been observed as deep as 74 feet bgs (WS-16) and is present as a free-phase within a well screened between 70 to 85 feet bgs (WS-15-85). Silt layer(s) within the alluvial WBZ appear to be controlling vertical and lateral DNAPL movement, with the DNAPL at these locations having likely migrated from areas beneath the adjacent effluent tar pond at Gasco, and/or from beneath the northern portion of the former 400-foot wide overflow area.

In addition to the preceding, DNAPL has been identified at a much greater depth between the former lowland area and the Willamette River at the extreme northern corner of Siltronic, where DNAPL has been identified at the base of two deep wells (WS-11-125 and WS-14-125), screened well below the base of the river at a depth between 110 and 125 feet bgs.

The deeper penetration of DNAPL at the Siltronic property relative to the Gasco property corresponds with the greater depth of dissolved phase impact to groundwater down-gradient of the former lowland area. Observation of soil conditions, as well as the resulting groundwater plume distribution, suggests deep penetration of DNAPL may have occurred in proximity to the Gasco/Siltronic property boundary (B-32 and B-33) and/or near the western end of the Fab 1 structure (WS-16, B-1-8). The significantly deeper DNAPL and resulting dissolved phase plume identified at the northern portion of Siltronic may be a function of commingling with the Siltronic trichloroethene plume, which as a dense solvent, may promote deeper transport of the less dense petroleum. Both the lateral and vertical extent of the deep DNAPL occurrence, as well as the dissolved phase groundwater plume, have been well delineated beneath the uplands.

With regard to off-shore conditions, a significant number of borings have been installed off-shore of the WS-11-125 and WS-14-125 location. Direct observation of upland and in-water soil core indicate the upland DNAPL to be wholly disconnected and separate relative to the shallow oily sediments identified at off-shore locations. The preceding indicates that the presence of oil and tar in shallow river sediments is likely attributable to historic discharge/overflow from the former tar effluent pond area (Gasco) and the adjacent lowland area (Siltronic).

Due to the depth of the DNAPL; the density of the DNAPL; and the apparent presence of a downward hydraulic gradient beneath the river, the DNAPL identified at the upland nearshore locations does not appear to be a future migration threat with regard to the river.

1.3 Supplemental Data Needs

Based on the description and evaluation of DNAPL occurrence at the Gasco and Siltronic properties as described herein, the following supplemental data needs have been identified.

- A thin zone of DNAPL was identified across a depth of 58 to 59 feet bgs at well PW-01-80, located between the river and the former tar effluent pond area. A sample of this DNAPL should be collected, if possible, for chemical and physical property evaluation so that general DNAPL properties may be more completely understood and so that common or unique attributes relative to DNAPL at other locations may be evaluated. Additionally, offshore investigatory activities should be conducted that focus on the area offshore of the PW-01-80 well location such that subsurface lithology can be determined and correlation of the upland DNAPL occurrence to sediment impacts may be made.

- DNAPL present within Siltronic alluvial wells WS-11-125, WS-14-124, and WS-15-85 and surficial fill WBZ well WS-10-27 should be sampled for chemical and physical property analyses such that comparison with DNAPL from other areas may be made and so that general DNAPL properties at these locations may be more completely understood.

- The installation of deep push probe borings at several key locations may supplement the understanding of the overall source area within the former lowland area (Siltronic) and/or the former tar effluent pond area for DNAPL identified at the PW-01-80, WS-11-125, and WS-14-125 wells, as follows:

  - One push probe boring at the extreme northern portion of the former overflow area near the western end of Siltronic's Fab 1 building, as near to B-1-8 as feasible in order to determine if the shallow DNAPL previously identified in the surficial fill at this location is accurately portrayed, and if so, whether this area is a possible source for deeper DNAPL occurrences.

  - Two deep push probe borings between the former tar effluent ponds and the PW-01-80 location, with one boring installed midway between MW-8-56 and PW-01-80, while the other boring would be installed midway between boring B-32 and PW-01-80. These borings will help determine if transport to the PW-1-80 location occurred from the eastern tar effluent pond area (near Siltronic) or from the western tar effluent pond area (near the former effluent discharge area).

2.0 INTRODUCTION

This document has been prepared at the request of the Oregon Department of Environmental Quality (DEQ) to provide a description of the known distribution of oil as a dense non-aqueous phase liquid (DNAPL) related to historical management of manufactured gas plant (MGP) wastes at the NW Natural Gasco site, 7900 NW St. Helens Road, and at the adjacent Siltronic Corporation (Siltronic) property, 7200 NW Front Avenue, Portland, Oregon between the years of 1913 and 1956.

DNAPLs are separate phase hydrocarbon liquids that are denser than water and may exist in the subsurface soil matrix either as a free-phase (pumpable) liquid or as residual liquid trapped within the soil porosity. The use, generation, and management of oil and tar byproducts during historical MGP operations has resulted in the release of dense oils to the subsurface at portions of the Gasco property, and extending to the northern portion of the adjacent Siltronic property.

As described herein, all MGP process activities were confined to the current NW Natural Gasco property, while MGP-related disposal practices occurred on portions of the Gasco property, as well as within a small depression and an approximate 400-foot wide strip of former lowland immediately south of the Gasco site on the present-day Siltronic property.

The primary objective of this document is to provide a summary of historical operations, contaminant sources, and hydrogeological conditions to support an evaluation of whether DNAPL present in upland portions of the Gasco and Siltronic properties may be a current or potential future source of DNAPL impact to sediments within the Willamette River. This information will be used to determine the need for additional data collection and/or for the development of a DNAPL-related source control action.

NW Natural has already agreed to implement a DNAPL-related source control action for an approximate 1-acre portion of the Gasco site (i.e., former effluent discharge/lowland area) following the investigatory activities described in the *Supplemental Remedial Investigation Report* (HAI, 2005a). A technology and alternatives screening for the development of a source control action in this area has been submitted to the DEQ. See *Preliminary Identification of Technologies and Alternatives DNAPL Focused Feasibility Study: MW-16 Area Technical Memorandum* (HAI, 2005c).

3.0 SITE DESCRIPTION

The Gasco property occupies 44.65 acres and the Siltronic property occupies 85 acres along the western bank of the Willamette River in a section of northwest Portland zoned by the city as “Heavy Industrial”.

The Gasco property is situated approximately 2,000 feet upriver of the St. John’s Bridge and extends approximately 1,600 feet upriver to a common property boundary with Siltronic. The Siltronic property extends approximately 2,000 feet upriver from the shared Gasco property line to the berm of the Burlington Northern Santa Fe Railroad Company (BNSF) Willamette River bridge crossing (Figures 1 and 2).

Site surface features include buildings, storage tanks, and equipment used in industrial processes currently ongoing at these properties (Figure 2). The Gasco property ranges from mostly paved or gravel-covered in the southwestern, western, and central portions of the property, to mixed grass and trees in the northern and southeastern portions of the property. The eastern corner of the property (former tar effluent pond area) occupies approximately 8 undeveloped acres, and is primarily covered with grasses and trees, with a small (approximately 3/4-acre) seasonal pond feature (Figure 3).

The Siltronic property is mostly covered with buildings or pavement across the northern and northwestern areas (the area closest to the shared property line with NW Natural), with grassy or undeveloped portions of the site remaining across the southern and eastern portions of the property.

Additional site features include a utility easement that crosses both the Gasco and Siltronic properties. This easement contains two abandoned Olympic Pipeline pipes, two active Olympic Pipeline pipes (oil and gasoline), a natural gas pipeline, a water supply pipeline, and a sanitary sewer pipeline (Figure 2).

The ground surface at the Gasco site slopes gradually northeastward towards the Willamette River with surface elevations ranging from approximately 38 feet above mean sea level (msl-City of Portland datum) at the southwestern portion of the property to approximately 23 to 30 feet msl at the top of the river bank. The Siltronic property is generally level with an average elevation ranging from approximately 32 to 35 feet msl.

The river bank at the Gasco site is composed of areas of rip-rap and areas of non-armored soils, and slopes steeply to an elevation of approximately 5 to 8 feet msl, below which exists the shoreline with a more gradual slope. The entire shoreline at the Siltronic property dips steeply to an elevation of approximately 0 feet msl and has been armored with rip-rap and geotextile fabric.

4.0 CURRENT SITE USE

4.1 NW Natural Gasco Property

The central portion of the Gasco site is currently used by NW Natural as a liquefied natural gas (LNG) storage and distribution facility, while the southern portion of the site is leased by Koppers, Inc. (KI) for use as a coal tar pitch distribution facility, and the northern portion of the site is leased by Fuel and Marine Marketing, Inc. (FAMM) for use as a bulk fuel storage and distribution terminal. The eastern (former tar effluent ponds), western (former office area), and northern (undeveloped) corners of the property are presently not used and have limited to no development.

4.1.1 *Liquefied Natural Gas Storage*

NW Natural (then NW Natural Gas Co.) constructed the company's first LNG storage tank on the Gasco site in 1969. This LNG storage facility is used to liquefy natural gas during times of low peak demand for storage until the gas is needed during times of peak demand, typically during the winter heating season. In addition to the LNG storage tank, NW Natural maintains LNG storage control and distribution facilities at the site. The portion of the site utilized for LNG storage contains the former tar processing area and the former naphthalene plant, tar thickeners, and above ground relief holders (Figure 3).

4.1.2 *Coal Tar and Pencil Pitch Distribution*

Koppers, Inc. (Carbon Materials and Chemicals Division), currently leases the southwestern portion of the Gasco site (approximately 6.4 acres) at 7540 NW St. Helens Road.

Koppers, Inc. (KI) imports coal tar pitch via bulk and/or liquid cargo vessels. The product is then stored at the site prior to distribution via tank truck or tank rail cars. Prior to 2005, solid coal tar pitch (e.g., pencil pitch) would arrive at the site by truck, while liquid coal tar pitch is imported via a bulk cargo vessel. Liquid coal tar pitch operations at the facility began in 1999, with the objective being the phase out of management of solid pencil pitch. As of 2005, management of solid pencil pitch at the site has been primarily phased out. The liquid coal tar pitch is received at the NW Natural Gasco dock on the Willamette River, where it is pumped from the vessel, through a heated aboveground pipeline to a storage tank on the KI lease area. KI formerly retained stockpiles of solid pencil pitch on site in a large structure located near the eastern corner of its lease area. This structure is presently empty, with the exception of pencil pitch residue throughout. The KI lease area is the location of the former MGP light oil plant and the Koppers coal tar pitch distillation plant.

4.1.3 *Marine Fuel Storage and Distribution*

Pacific Terminal Services, Inc. (PacTerm), under contract with Fuel and Marine Marketing (FAMM), operates a fuel storage and distribution facility at the northern portion of the site. From 1965 and until FAMM's involvement in 1999, the distribution facility was operated by Pacific Northern Oil (PNO). The terminal receives, stores, blends, and ships marine fuels and lubricants, utilizing both barge and truck for transport. FAMM uses two aboveground storage tank (AST) farms for storage and distribution of fuel. The portion of the site leased by FAMM contains former MGP above-ground oil storage tanks, the former briquette storage building area, and spent oxide storage pile area (Figure 3).

4.2 Siltronic Property

Wacker Siltronic purchased the property south of Gasco in 1978 for the purpose of constructing a silicon wafer fabrication plant. Since 1980, Siltronic has manufactured silicon wafers from silicon crystal ingots, which involves ingot slicing, lapping, etching, polishing, epitaxy and cleaning operations (MFA, 2004a). Buildings consist of two manufacturing FABs, facilities support for pure water, boilers and chillers, utility support for air compressors and emergency generators, warehouse, wastewater treatment, administrative offices, and a large vehicle parking area (Figure 2).

5.0 HISTORICAL SITE USE

5.1 Overview

Portland Gas & Coke (PG&C) constructed an oil MGP, known as the Gasco facility, on the Gasco property in 1912 and 1913, with operations beginning in late 1913. Company records indicate that site preparation involved the filling of approximately 10 acres of low-lying land with 205,381 cubic yards of material dredged from the Willamette River. PG&C production areas were located along the western portion of the Gasco property (e.g., present day KI Lease and LNG Plant areas), extending to locations near the riverbank at the central portion of the property (e.g., present day FAMM Lease area). An extensive description of the production methods used at the PG&C Gasco site is provided in the *Updated Phase I Site Characterization Summary Report, Siltronic Facility* (HAI 2005b) and is not repeated herein. MGP waste/residue management areas were historically located in a lowland/unfilled area near the eastern corner of the property (effluent discharge, effluent ponds, and lampblack storage), and at the northern corner of the property (spent oxide / gas purifier waste storage piles).

The Siltronic property, located immediately south (upriver) of the Gasco property, was unused and unoccupied until the construction and operation of the Western Transportation fueling docks in the eastern corner of the site. The exact dates of operation of the Western Transportation facilities are not known; however, the company owned the property between 1943 and 1968. Western Transportation operated a refueling station for tugboats that included fuel storage and dispensing facilities.

PG&C owned a portion of the Siltronic property from 1939 until 1962, during which time company records and aerial photograph review (HAI, 2005b) indicate waste management activities were conducted on a portion of that property. Specifically, and as described in Section 5.2.2 below, these waste management activities were limited to the northern portion of the Siltronic property and occurred between approximately 1941 and 1956 (HAI, 2005b). No MGP production areas were located on the footprint of the current Siltronic property. PG&C transferred interest in the property in 1962.

5.2 PG&C MGP-Related Waste Management Areas

Active MGP waste management activities occurred on the Gasco property throughout the plant's life (1913 through 1956), while MGP waste management activities on the adjacent Siltronic property occurred between the approximate 1941 through 1956 timeframe (PG&C owned the property from 1939 to 1962). Below is a brief description of the MGP-related waste management areas of potential DNAPL source that were located at the Gasco and Siltronic properties, based on review of aerial photographs and company records (HAI, 2005b). Table 1 identifies by-products or wastes generated by the Gasco MGP, including a description of the material and the associated chemicals of interest.

5.2.1 Gasco Property

<u>Former Effluent Discharge/Lowland Area</u>: Historical facility records indicate the primary facility sewer outfall was formerly located south of the current southernmost FAMM fuel storage tank area, which in turn discharged directly to the Willamette River. Further, historical aerial photographs from 1936 and 1940 indicate lampblack storage and effluent discharge (either emanating from the sewer, or from overland discharge) to this area. Remedial Investigation (RI) activities completed at the Gasco facility have confirmed the presence of MGP byproduct wastes in the area of the former discharge, with the presence of buried bulk tar on the former ground surface along with underlying oil, as well as tar mixed into soils and used as fill at this portion of the site. Discharges of oil and tarry effluent to this area would have subsided in 1941, at which time these effluents were instead directed to the effluent tar pond area located near the eastern corner of the property (described below). Tar, which is solid to semi-solid, has not migrated from where it was placed or mixed into the soils, is not a DNAPL. Instead, oil (DNAPL) has been identified below the former ground surface within the former effluent discharge area, correlating to the area of historic discharge.

Filling of the effluent discharge/lowland area was initiated in 1972 (November 1972 photograph) with placement of large rock on the ground surface along the present-day shoreline, with in-filling behind. Company records indicate the area behind the shoreline was subsequently filled with imported quarry rock and site soils in a 3 to 1 blend with tar from this area and the adjacent tar pond area. Subsurface boring log data indicate that fill used to form the embankment adjacent to the river did not contain tar. This area presently consists of approximately 25 to 30 feet of fill material above the former ground surface (silt unit or other native alluvial materials).

<u>Former Effluent Tar Pond Area</u>: The effluent tar settling ponds (one large, approximately 3-acre pond and one small approximate 0.5-acre elongate pond) were constructed near the eastern corner of the current Gasco property and came on-line in 1941. These effluent ponds received wastes from tar boxes and lampblack dryers (tar, lampblack, oil, and oil-water emulsions), and were meant to reduce the discharge of effluent to the river. As shown on aerial photographs (HAI, 2005b), the smaller effluent pond straddled the border of the current Siltronic property (Figure 3).

PG&C records indicate the larger tar effluent pond was designed to overflow via a weir into the western end of the narrow effluent pond located on the current NW Natural / Siltronic property boundary. This pond, in turn, was designed to overflow via a weir on the eastern end into a channel that directed discharge to the Willamette River at a point near the current NW Natural / Siltronic property line (Figure 3). As described in Section 5.2.2, the outlet from this pond to the Willamette River was apparently blocked in 1951 and overflows from these ponds were instead directed to the lowland area present in the approximate 400-foot wide former lowland area of the Siltronic property adjacent to the current property boundary (HAI, 2005b).

In 1973, filling and reconfiguration of the large settling pond located on the Gasco property began (May 1973 aerial photograph). Company records indicate this pond contained an estimated 30,000 to 40,000 cubic yards of tar, which was mixed with quarry rock and spent iron oxide material from the northern portion of the property in a 3 to 1 blend (3 cubic yards rock/spent oxide/soil to 1 cubic yard tar). Subsurface boring log data indicates that fill used to form the embankment between the river and the effluent ponds did not contain tar. This area presently consists of 25 to 30 feet of tarry fill. Tar, which is solid to semi-solid, and has not migrated from where it was placed or mixed into the soils, is not a DNAPL. Instead, DNAPL (oil) has been identified beneath the former ground surface (beneath the fill) within the former tar effluent pond area. The oil in this area may represent both direct discharge of oil and oil/water emulsions to the former ground surface during operation of the effluent ponds, as well as possible historic separation of an oily fraction from the tar during cooling and prior to solidification.

5.2.2 Siltronic Property

<u>Former 400-foot Wide Lowland Area</u>: Immediately south of the common Siltronic/Gasco property line, this approximate 10-acre area received overflow from the Gasco effluent tar pond (potentially including tar and tar/oil/water emulsifications) and from direct placement of MGP residuals derived from the clean-out of the effluent tar ponds. Clean-out activities, conducted to maintain capacity within the effluent ponds, reportedly involved removal of tarry wastes from the base of the Gasco ponds, with placement

within the adjacent Siltronic lowland area. Based on operational history, clean-out activities would have occurred between 1941 and 1956, while overflow apparently began in 1951 and also would have ended in 1956. Tar thickness measurements made in 1960 (2 to 6 feet of tar across much of the area) indicate approximately 40,000 cubic yards of tarry materials may have been present in this area subsequent to cessation of all MGP-related activities at the Gasco site, which occurred in 1956 (HAI, 2005b). Tar, which is solid to semi-solid and has not migrated from where it was placed or mixed into the soils, is not a DNAPL. DNAPL (oil) has been identified both within the fill and beneath the former ground surface (beneath the fill) in portions of the former lowland area.

<u>Former Depression or Excavation</u>**:** South of the former lowland area, approximately 2 to 3 feet of tar was identified at the base of this approximate 0.5-acre apparent excavation when evaluated in 1960 (HAI, 2005b). This feature was first observed in aerial photographs dated 1955. Estimates based on tar thickness measurements made in 1960 indicate approximately 2,000 cubic yards of tarry materials (not DNAPL) may have been present in this area subsequent to cessation of all MGP-related activities at the Gasco site. The function of this depression / excavation is unknown. DNAPL has not been identified beneath the fill at this location.

5.3 Other Potential Contaminant Source Areas

Sources of potential NAPL impact other than the MGP-related waste management areas described above exist on the Gasco and the Siltronic properties. These contaminant source areas are summarized below.

5.3.1 Gasco Property

<u>Koppers Company Land Disposal Area</u>: As described within a 1994 *Site Inspection Prioritization Report* prepared for the EPA by URS Consultants, Inc., KI's predecessor, Koppers Company, Inc. (Koppers), operated a coal tar distillation facility at the southern portion of the property from 1966 to 1973. During this timeframe Koppers produced chemical oil, creosote, and pitch from coal tar distillates. From 1974 through 1977 Koppers manufactured electrode grade pitch, a product derived from both coal tar and

petroleum residuals. From 1977 through the present, Koppers, and now KI, has used the facility as a terminal for the bulk transfer and distribution of liquid creosote coal tar and solid coal tar pitch. This portion of the property contains the former MGP light oil plant, tank farm, pitch plant, coke ovens, and tar processing areas (Figure 3).

With regard to waste disposal practices, Koppers reportedly generated approximately 1,500 gallons of wastewater per day during the timeframe that the plant was used as a coal tar distillation facility (CDM, 1987). Koppers land disposed of these wastewaters at the eastern portion of their facility, a location immediately west of the former tar settling ponds, coinciding with the location of the current pencil pitch storage structure (Figure 3). These wastewaters may have resulted in impacts to the subsurface, and are a potential DNAPL source. The Koppers land disposal area is depicted in 1966, 1968, and 1972 aerial photographs of the site, as suggested by the presence of apparent above-ground piping and staining. Surface staining is apparent across the Koppers Lease area as depicted in a 1972 aerial photograph (HAI, 2005b). As described in Section 9.2.2.1, DNAPL in this area appears present in both residual and free-phase forms, with free-phase DNAPL stratigraphically trapped above an underlying silt unit.

<u>MGP and Koppers Operational Areas</u>: Most MGP operational areas and the Koppers operational areas of the site were located along the western portion of the Gasco site in the area currently occupied by the KI Lease Area and the LNG plant (Figure 3). Impacts attributable to spills and leaks related to various operational areas of the site are apparent based on the identification of shallow soil impacts, including oil (DNAPL). As described in Section 9.2.2.1, DNAPL in these areas appears present in both residual and free-phase forms, with free-phase DNAPL stratigraphically trapped above an underlying silt unit.

5.3.2 Siltronic Property

<u>Olympic Pipeline Petroleum Release(s)</u>: The Olympic Pipeline utilizes two fuel product lines (diesel and kerosene; gasoline) within a utility corridor that traverses the central portion of the Siltronic property. Line failure resulting in product release and soil and groundwater impacts was identified near the

western corner of the Siltronic facility in 1979, proximate to the 400-foot wide former lowland area. Due to the nature of the petroleum products carried by these lines (lighter end hydrocarbons), this area is not a suspected source for DNAPL, but would instead be a suspected source for light (less dense than water) NAPL (LNAPL). LNAPL has not been identified in any monitoring wells at the property.

Western Transportation Petroleum Release(s): Western Transportation operated a petroleum fueling dock at the eastern corner of the Siltronic property between approximately 1930 and 1950. Possible surface staining was noted on a 1970 aerial photograph, and petroleum impacts to soil, likely attributable to these activities, have been identified. Depending on the nature of the fuel managed by Western Transportation, any releases associated with these operations could have been in the form of either DNAPL or LNAPL. As described in Section 9.2.2.2, the NAPL identified at this location appears to be in residual, non-mobile form.

Siltronic-Related (Non-Petroleum) Releases: Trichloroethene (TCE) leaked from an underground storage tank system operated by Siltronic at the northern portion of the property resulting in soil and groundwater impacts. As indicated in DEQ correspondence (DEQ, 2005), TCE concentrations identified beneath the silt unit near the TCE release area (43,000 ppb to 575,000 ppb) are suggestive of a release of chlorinated solvent in a non-aqueous phase (DNAPL). Because petroleum is highly miscible with degreasing solvents such as TCE, the presence of TCE could be expected to impact the fate and transport of petroleum in the subsurface.

Filling Activities: After the property was sold by NW Natural, site filling activities were conducted on the Siltronic property between 1966 and 1975. Filling involved placement of 1.5 million cubic yards of material on the property, including approximately 700,000 cubic yards of dredge spoils from unidentified locations and 800,000 cubic yards of material imported from a quarry. Depending upon origin, dredged sediments could reasonably have been impacted by many different sources of potential contamination, including ship traffic, industrial operations (such as MGP, wood treating facilities, shipyards, pesticide manufacturing, or petroleum terminals), agricultural activities, or urban run-off, with these impacts potentially being in the form of NAPL at the time of filling. During the time of filling activities, the property was owned by Mr. Victor Rosenfeld and Mr. H.A. Anderson.

In addition to possible sources of impact from the dredged sediments or other imported materials used as fill, observations of tar or oil during various investigations or construction activities at the Siltronic site, as well as dark soils visible in aerial photographs between 1967 and 1971 suggest the possibility that MGP-related wastes from the 400-foot wide lowland area may have been redistributed and combined with fill placed at various portions of the Siltronic property during filling activities (1966-1975), after NW Natural sold the property in 1962 (HAI, 2005b).

As described in Section 9.2.2.2, NAPL attributable to filling activities has not been identified beneath the silt unit and appears present in residual, non-mobile form.

6.0 SUMMARY OF POTENTIAL NAPL CONTAMINANT SOURCES

Based on the description of historical uses of the Gasco and Siltronic properties, as described in Section 5, potential petroleum-related NAPL sources present on the Gasco and Siltronic properties are listed below, and are depicted on Figure 3.

NW Natural Gasco Property – Process Areas

- Retort Area
- Tar Processing Area
- Light Oil Plant/Koppers Plant; Tank Farm
- Naphthalene Plant
- Coke Oven Area
- Pitch Plant/Tar Loading Area

NW Natural Gasco Property – Waste Management Areas

- Former Effluent Discharge Area
- Former Tar Effluent Settling Pond Area
- Former Koppers Land Disposal Area
- By-Product Incorporation into Fill

Siltronic Property – PG&C Waste Management-Related Areas

- Former 400-foot Wide Lowland Area (oily effluent placement)
- Former Depression or Excavation (possible oily effluent placement)

Siltronic Property – Non-PG&C Waste Management-Related Areas

- Post PG&C By-Product Incorporation or Impacted Fill Use
- Western Transportation Area (fuel oil spills)
- Olympic Pipeline

7.0 GEOLOGICAL SETTING

7.1 Surficial Fill Unit

As described in Section 5.0, much of the Gasco and Siltronic properties have been extensively filled through time. At the Gasco property, fill consists of dredge material placed at the western and central portions of the site prior to development in 1913. Remaining low-lying areas, primarily to the north, east and southeast (northern spent oxide stockpile storage; effluent discharge/low area and effluent tar pond areas) received MGP by-product placement to the former ground surface over various time intervals as described in Section 5.0. Further, MGP by-products, were mixed with soil and quarry rock and used as fill for the eastern portion of the Gasco property (former effluent tar pond and adjacent effluent discharge areas), with filling predominantly complete by 1975.

At the Siltronic property, fill consists of dredged materials as well as imported quarry rock placed on the property during the 1966 to 1975 timeframe to ready the site for development. Prior to filling, during the 1941 to 1956 timeframe, the former northern lowland portion of the Siltronic property received MGP waste as described in Section 5.2.2. Further, in places the fill has been found to contain impacts potentially attributable to re-distribution of MGP residues at the site, and/or as a function of a multitude of sources that may have impacted dredged sediments prior to placement on the site (e.g., current/former ship maintenance, pesticide manufacture, wood treatment, MGP, and petroleum transfer facilities are all located along the river in proximity to the site). All fill-related activities at the Siltronic property were conducted by others after NW Natural sold the Siltronic parcel in 1962.

An isopach map depicting the thickness of the surficial fill unit across the Gasco and Siltronic properties is included as Figure 4. The thickness of the surficial fill unit across the site ranges from approximately 2 to 25 feet near the Tualatin Mountains (MW-12 to RP-3-61) to a maximum of 35 to 42 feet in the central – northern portion of the Siltronic property, as observed at boring locations for wells WS-15 and WS-17. Along the bank of the Willamette River, the surficial fill unit ranges in thickness from approximately 24 to 34 feet. Fill identified adjacent to the river was predominantly found to consist of fine- to coarse-grained sand and gravelly sand, with occasional concrete, brick, or glass fragments. However, at several locations, a much finer-grained material, predominantly a sandy silt to silt with occasional gravel, was identified.

7.2 Alluvial Unit

Below the surficial fill is a laterally extensive upper fine-grained silt unit (the top of which corresponds to the former ground surface), which acts as a confining to semi-confining unit across much of the Gasco and Siltronic properties. Although laterally extensive across a majority of the Siltronic and Gasco properties, the silt unit has been found to be absent below some upland near-shore areas at the Gasco property. The silt unit is typically found to exhibit coloration ranging from olive gray to green, with some areas of orange-brown mottling, with small sand lenses and vertical rootlet zones present within portions of the silt unit.

Figure 5 provides elevation contours for the surface of the silt unit using available data from both the Siltronic and the Gasco properties. As depicted on Figure 5, the surface of the silt unit generally slopes from all directions to the central portion of the Siltronic and Gasco sites, with the overall low being identified on the Siltronic property in the central portion of the former northern lowland area, where the top of silt was identified at an elevation of approximately -8 feet msl (boring WS-15). The silt surface rises from the WS-15 area in a riverward direction, reaching a crest beneath the Fab 1 building (at 9 to 12 feet msl), beyond which the surface slopes back down towards the river, with an elevation of between 2 and 6 feet msl identified adjacent to the riverbank at the northern portion of the property.

A map depicting the thickness of the upper silt unit across the Siltronic and Gasco properties is included as Figure 6. As depicted on Figure 6, the thickness of the upper silt unit is greatest throughout the central portion of the Siltronic property, where thicknesses of 67 feet (WS-10), 69 feet (B-104), and 56 feet (WS-3-81) were identified, and extending to the northwest where thicknesses of up to 43 feet (MW-14) have been identified on the Gasco site. The thickness of the silt unit at both the Siltronic and Gasco sites decreases in the direction of the Willamette River, where thicknesses of between 1 and 3 feet are common, or in some cases, the silt appears locally absent and/or transitions into a silty sand towards the shoreline, becoming thicker at the shoreline and offshore of the shoreline.

Beneath the silt unit, the alluvial deposits are found to typically consist of sand with interbedded lenses of silt, sandy silt, or silty sand. The sands within the alluvial unit are described as grey in color with localized areas of brown coloration, fine-grained, well sorted / poorly graded, sub-round to angular, and locally micaceous. The silt / sandy silt lenses identified within the sand were typically grey in coloration, and typically contain rootlets and shell fragments. A thin layer consisting of medium to coarse-grained sandy gravel has been observed at the base of the alluvial deposits at both the Siltronic and Gasco properties.

7.3 Columbia River Basalt Group

Figure 7 provides elevation contours for the surface of the bedrock using available data from both the Siltronic and Gasco properties. These data indicate the basalt surface dips steeply to the northeast across the Gasco and Siltronic properties, with the top of the basalt occurring at a depth of approximately 36 feet below ground surface (bgs) near the southern corner of the Gasco site (boring MW-12-36), to depths of 215 feet bgs near the northern corner of the Siltronic site (boring B-1-8). Although, in general, the bedrock surface is anticipated to dip steeply from the Tualatin Hills towards the Willamette River, undulations in the surface are observed. Investigatory activities conducted by Geraghty & Miller (1991) near the southern corner of the Siltronic property, as well as results of investigatory activities completed by URS Greiner Woodward Clyde (URS) along the southeastern Siltronic property boundary, indicate the presence of a bedrock high, with the bedrock surface occurring at a depth of 108 to 115 feet bgs near the locations of wells RP-7 and WS-3, and rising towards the east corner of the Siltronic site adjacent to the Willamette River, where bedrock was encountered at a depth of 63 feet bgs at boring RP-1. Additionally, recent investigatory activities completed by Siltronic within the Willamette River (MFA, 2005), indicate that the bedrock surface elevation rises to a depth of approximately 90 feet bgs (relative to the Siltronic ground surface), within approximately 500 feet of the northern Siltronic shoreline. The new data will be used to update the overall bedrock elevation contour map once locational data for the borings are obtained.

8.0 HYDROGEOLOGICAL SETTING

Groundwater occurs in three hydrologic zones beneath the Siltronic and Gasco properties: the unconfined surficial fill water-bearing zone (WBZ), the semi-confined alluvial WBZ, and the confined bedrock aquifers of the Columbia River Basalt Group. Cross-sections (Appendix A) depict the distribution of these zones across the Gasco and Siltronic properties.

8.1 Surficial Fill Water-Bearing Zone

The saturated thickness of the surficial fill WBZ ranges from 1 to 5 feet adjacent to the river, to between 10 and 20 feet across the central, southern, and western portions of the Gasco/Siltronic area. Overall groundwater flow direction across a majority of the Gasco/Siltronic area is to the northeast, towards the Willamette River. A groundwater divide exists near the southern and western portions of the Siltronic property, with flow back to the south and toward North Doane Creek (HAI, 2005b).

Responses to tidal fluctuations in the adjacent Willamette River are not expressed or are extremely muted in the surficial fill WBZ at Gasco or Siltronic well locations, indicating this zone is predominantly isolated from the river. A downward hydraulic gradient between the surficial fill WBZ and the alluvial WBZ is typical across the Gasco/Siltronic area. As such, groundwater in the surficial WBZ may migrate to the alluvial WBZ in areas where the intervening silt unit thins or otherwise does not impede downward flow.

8.2 Alluvial Water-Bearing Zone

Beneath the surficial fill WBZ, and defining the surface of the alluvial unit, is a laterally extensive fine-grained silt unit (as described in Section 7.0). The silt unit beneath the Gasco and Siltronic properties has been found to range in thickness from approximately 70 feet near the central portion of the

Siltronic property, thinning toward the river, where thicknesses of 1 to 3 feet are common at the riverbank. Beyond the riverbank, a thickening prism of silt has been identified (HAI, 2005a,c). Vertical migration of contaminants through the silt unit has been limited to the northern corner of the Siltronic property (within the 400-foot wide former lowland area) and eastern corner of the Gasco property, where vertical fingering of oil (DNAPL) through the silt unit and into alluvial WBZ has occurred.

The alluvial WBZ consists of interbedded sands and silts underlying the silt unit, and ranges in thickness from 2 to 25 feet thick at the central and western portions of the Gasco/Siltronic area, to up to 175 feet adjacent to the river, near the eastern corner of Gasco / northern corner of Siltronic. Overall groundwater flow direction in the alluvial WBZ is to the northeast toward the Willamette River, although a more northern component of flow is apparent at the basal portions of the alluvial WBZ (HAI, 2005b).

The overall vertical gradient in the alluvium is predominantly downward in the upper portions of the alluvial WBZ, and upward across the lower portions of the alluvial WBZ, with the greatest horizontal gradient identified at locations further away from the river and at intermediate depths (e.g. 100 to 125 feet bgs).

As described in recent reports prepared by HAI (HAI, 2005a,b), and as depicted in cross-sections (Appendix A), a relatively thick (>10 foot) layer of silt is present in nearshore sediments adjacent to the Gasco and Siltronic sites, extending 200 to 300 feet from the shoreline. It is expected that the fine-grained silt materials impede nearshore discharge of groundwater to the river from both the surficial fill and the upper portions of the alluvial unit.

Water levels measured in offshore well points (MFA 2005) identified a predominant downward gradient throughout the alluvial WBZ beneath the Willamette River, indicating the river near the Siltronic and Gasco properties may be a losing reach.

Available vertical gradient data and contaminant concentration profiles adjacent to and beneath the Willamette River are not suggestive of the discharge of groundwater from intermediate to deep portions of the alluvial WBZ to Willamette River sediments (MFA, 2005).

8.3 Columbia River Basalt Group

As impacts characteristic of MGP wastes have not been identified in the basal portions of the Alluvial WBZ, the Columbia River Basalt Group is not monitored at the Gasco or Siltronic properties.

9.0 DENSE NON-AQUEOUS PHASE LIQUID

DNAPL is a separate phase hydrocarbon liquid that is denser than water. When DNAPL such as creosote or heavy oil is released to the environment, it will migrate vertically through the unsaturated zone and may spread laterally above the water table until sufficient accumulation occurs such that gravitational pressure exceeds the entry pressure of the underlying capillary fringe. Below the water table, and if the DNAPL volume is sufficient, it will move downward as a function of gravitational force through the soil matrix until an impermeable barrier (silt or clay) is encountered, upon which it may pool and/or continue to migrate laterally until the DNAPL source is exhausted or until another impermeable material is encountered. As the DNAPL moves it leaves behind disconnected blebs or ganglia of DNAPL trapped by capillary forces in pores or small scale heterogeneities (residual DNAPL). The direction of DNAPL flow is more a function of gravity, the slope of the impermeable barrier, and the distribution of capillary forces, than as a function of groundwater advective flow processes (Cohen and Mercer, 1993).

DNAPL will occur in the subsurface as either a free-phase or residual liquid. Residual DNAPL is immobile (trapped by capillary forces within the pores) and will not move into a well open to the atmosphere. Free-phase DNAPL is present under pressures greater than atmospheric pressure, and will therefore accumulate in wells that are open to the atmosphere. Free-phase DNAPL will either have the ability to migrate, or it may be immobilized due to the presence of down-dip (underlying or adjacent) impermeable barriers (e.g., be stratigraphically trapped), where it may pool. Residual saturation levels for an MGP or creosote site may range from 5 to 50% of the total pore volume (EPA, 1992 and Jackson, et.al., 2004), while immobilized pools of DNAPL may exist at localized saturation levels of up to 70% (U.K. Environment Agency, 2003).

DNAPL, both as residual immobile product, and in more limited areas, as free-phase liquid (as identified by accumulation within monitoring wells), have been identified at both the Gasco and Siltronic properties. Potential sources for the DNAPL are described in Section 5.0. At Siltronic, the presence of DNAPL attributable to MGP-related activities is limited to waste management-related sources on the northern portion of the property (e.g., where effluent pond overflow and tar placement activities were previously conducted by PG&C between 1941 and 1956). Residual petroleum-related DNAPL not attributable to MGP-related waste management activities exists elsewhere in the surficial fill at the Siltronic property, likely a function of the use of impacted fill and/or the mixing of MGP waste residues into the fill subsequent to PG&C's transfer of interest in the property.

A description of locations at the Gasco and Siltronic properties where visual occurrence of NAPL has been noted within subsurface soil boring logs is included in Tables 2 (Gasco property) and 3 (Siltronic Property). Interpretation of the observed DNAPL as being either residual (non-mobile), stratigraphically-trapped free-phase (non-mobile), or potential mobile free-phase requires specific laboratory testing and/or interpretation based on the nature of the observation (patchy or visually saturated), evaluation of the underlying or adjacent stratigraphy, and/or the accumulation or lack of accumulation of DNAPL within a well. Interpretation of nature and extent of DNAPL is included herein under Section 9.2.

In addition to NAPL, Tables 2 and 3 also note the presence of tar within subsurface soils. As indicated previously, oil and tar are differentiated by their observable physical characteristics, with tar being a black, semi-solid to solid (often plastic to slightly elastic) material, and oil being a brown to black liquid that may be of variable viscosity. Tar, being a solid to semi-solid, is not a DNAPL.

Figures 8 through 10 depict the interpreted extent of NAPL across different subsurface horizons at the Gasco and Siltronic properties based on boring log descriptions, interpretation between boring locations, and descriptions provided by site personnel. Specifically, Figure 8 depicts the estimated lateral extent of DNAPL within the surficial fill unit; Figure 9 depicts locations where DNAPL has been identified in borings or wells within the underlying alluvial WBZ (beneath the alluvial silt unit) at any depth shallower than 100 feet bgs; and Figure 10 depicts locations where DNAPL has been identified at any depth within the alluvial WBZ greater than 100 feet bgs.

Because the DNAPL may exist as either: 1) mobile free-phase DNAPL; 2) stratigraphically trapped (immobile) free-phase DNAPL: or 3) as non-mobile residual DNAPL, Figures 8 through 10 include an estimation of the extent to which each of these phases occurs across the Gasco and Siltronic properties, as described in more detail in Section 9.2

The Table below summarizes those monitoring wells on either the Gasco or Siltronic properties where free-phase DNAPL has been identified within monitoring wells.

Well ID	**Location**	**Screen Interval (feet bgs)**	**WBZ Screened**	**Distance to Shoreline**	**DNAPL Accumulation (average)**
MW-06-32	Gasco: Retort Area	22 - 32	Surficial Fill	400 feet	2 to 6 feet
MW-10-26	Gasco: Tar Thickener, Light Oil Plant	16 - 26	Surficial Fill	750 feet	2 feet
MW-11-32	Gasco: Tar Pond; Koppers Land Disposal Area	22 - 32	Surficial Fill	700 feet	1.5 feet

Well ID	Location	Screen Interval (feet bgs)	WBZ Screened	Distance to Shoreline	DNAPL Accumulation (average)
MW-16-45	Gasco: Effluent Discharge Area	30 - 45	Alluvial	40 feet	2 to 6 feet
PW-01-80	Gasco: Tar Effluent Pond Area (down-gradient)	40 - 80	Alluvial	75 feet	0.2 feet[1]
WS-10-27	Siltronic: Former Lowland Area	11 - 26	Surficial Fill	900 feet	2 feet
WS-11-125	Siltronic: Former Lowland Area (down-gradient)	110 - 125	Alluvial	60 feet	1.5 feet
WS-14-125	Siltronic: Former Lowland Area (down-gradient)	110 - 125	Alluvial	60 feet	3 feet
WS-15-85	Siltronic: Former Lowland Area	70 - 85	Alluvial	500 feet	6 feet[1]

1 = Based on one measurement

As summarized above, and with regard to wells screened within the surficial fill WBZ, free-phase DNAPL has been identified in wells MW-6-32, MW-10-26, and MW-11-32, all located across the central portion of the Gasco property at distances of between 400 and 750 feet from the shoreline; and within surficial fill WBZ well WS-10-27 at the north/central portion of the Siltronic property, located approximately 900 feet from the shoreline. DNAPL has not been identified beneath the silt unit at any of these locations.

With regard to wells screened beneath the silt unit within the alluvial WBZ, free-phase DNAPL has been identified at the base of wells MW-16-45 and PW-1-80 near the former effluent discharge and effluent tar pond areas at Gasco (approximately 80 to 125 feet from the shoreline); and in wells WS-11-125 and WS-14-125 near the former effluent pond overflow area at

Siltronic (approximately 60 to 80 feet from the shoreline); and in well WS-15-85, located approximately 500 feet from the shoreline beneath the former lowland area at the northern portion of the Siltronic property.

All wells, as identified above, where free-phase DNAPL has been identified, are highlighted on Figures 8 (surficial fill WBZ), 9 (upper alluvial WBZ), and 10 (deep alluvial WBZ).

9.1 DNAPL Physical and Chemical Characteristics

DNAPL may be characterized by density, viscosity, interfacial tension with water, wettability, and chemical composition. These properties will impact DNAPL behavior in the subsurface.

Samples of DNAPL have been collected from surficial fill WBZ wells MW-6-32, MW-10-26, MW-11-32, WS-10-27, and alluvial WBZ wells MW-16-45 and WS-11-125. The DNAPL samples have been analyzed for certain physical and/or chemical composition analyses, the results of which are summarized on Tables 4 through 6. In general, fuel fingerprinting, viscosity, density, and direct observation indicate the DNAPL to be similar to a creosote or tar oil. Creosotes and tar oils are variable and complex petroleum mixtures, but generically consist of a dense dark oily liquid generated from the distillation of coal tar (as conducted by Koppers between 1966 to 1973), or tar oil (as conducted by the PG&C between 1913 and 1956). Specific descriptions of the DNAPL identified at the site, based on available physical/chemical analyses and observation, are provided below.

9.1.1 Physical Characteristics

Density

As summarized on Table 4, all tested oil samples have a similar specific gravity, ranging from 1.05 at wells MW-6-32 and MW-10-25 to 1.1 at well WS-11-125. This range of specific gravity (e.g., density) is consistent with that typically identified for a creosote/tar oil (1.04 to 1.10). A specific gravity greater than 1.0 indicates the oil will tend to move vertically downward in the subsurface in response to gravitational forces, however because the densities are only slightly greater than water, vertical migration would be slow as compared to a chlorinated solvent DNAPL such as TCE – which has a specific gravity in the range of 1.4 to 1.5 (Environment Agency, 2003). The greatest DNAPL density (1.1) was identified at the WS-11-125 location, corresponding to the location of the Siltronic TCE plume. TCE was identified as a component of the DNAPL at this location (see Section 9.1.2).

Viscosity

Viscosity is a measurement of the ability for a fluid to flow, with higher viscosity fluids requiring greater energy to initiate flow. Viscosity is highly temperature dependent, with fluids typically becoming less viscous (a greater ability to flow) at higher temperatures. With regard to DNAPL samples collected from wells MW-6-32, MW-10-25, and MW-11-32, viscosity tests were conducted at a temperature of 122°F, while the DNAPL sample collected from the MW-16-45 location was tested at three temperatures (70°F, 100°F, and 130°F). In comparing viscosity results between locations it is important to select results that were calculated at similar temperatures.

As summarized in Table 4, viscosity testing results indicate the most viscous oil (tested at 122°F) to be present within the surficial fill WBZ at the MW-11-32 location, proximate to the former Koppers land disposal area / former tar settling pond area (45.7 centistokes). Otherwise, viscosity testing results were relatively similar, with viscosities ranging from a low of 7.2 centistokes at well MW-6-32 (former retort/generator area) to a high of 18.7 centistokes (130°F) at the MW-16-45 location (former effluent discharge area). As an example of the influence of temperature, viscosity testing results of the DNAPL collected from the MW-16-45 location indicate a viscosity range from a low of 18.7 centistokes at 130°F to a high of 105 centistokes at 70°F. Ambient subsurface temperatures at the site, based on typical groundwater temperatures, ranges from approximately 55 to 60°F.

For comparison with the above-viscosities, and at approximately 130°F unless otherwise indicated, water has a viscosity of 0.55 centistoke, diesel fuel has a viscosity of 4 centistokes; olive oil has a viscosity of 24 centistokes, and honey has a viscosity of 73 centistokes (at 100°F). Viscosities reported for creosote (temperatures not indicated) typically range between 20 and 70 centistokes (Environment Agency, 2003).

Visually, oil from the MW-10-26 and the MW-11-32 locations appear similar, with a black coloration and thick "syrupy" consistency at ambient temperatures. Further, oil from the MW-6-32 and the MW-16-45 locations appear similar at ambient temperatures, with a dark brown coloration and a thinner "motor oil" consistency. Empirical evidence of relative viscosities (e.g., the ability to flow) were evaluated during pilot testing activities regarding DNAPL recovery that were conducted in 2000 (HAI, 2001), as well as DNAPL removal activities conducted at the MW-16-45 location in 2005 (HAI, 2005a). The preceding activities indicated relatively rapid movement of DNAPL into the evacuated borehole at the MW-6-32 and MW-16-45 locations (within hours), while DNAPL at the MW-10-26 and MW-11-32 location required days to weeks to flow back into the evacuated borehole, suggesting higher viscosities at the MW-10-26 and MW-11-32 locations, under ambient temperatures. The capacity of DNAPL to flow back into other wells has not been evaluated.

Wettability and Interfacial Tension

Wettability is a measure of a liquid's relative affinity for a solid. For example, a "wetting" fluid will preferentially spread over a solid surface (e.g., soil particle) at the expense of a "non-wetting" fluid. Thus, a strongly "water-wet" system would tend to result in lower residual NAPL saturation levels (e.g., greater mobility potential) than a strongly "NAPL-wet" system. Wettability testing results (HAI, 2005a) indicate that the DNAPL at the MW-16 area (former effluent discharge area at Gasco) had intermediate or neutral wettability. Potential residual saturation levels tend to be slightly lower in a neutrally wet system than in a strongly oil-wet or strongly water-wet system (Anderson, 1987).

Interfacial tension (IFT) refers to the tensile force that exists at the interface of two immiscible liquids. IFT is a measurement of a liquid's affinity for being trapped by capillary pressures in the subsurface. IFTs for contaminants typically encountered in the subsurface generally range from 5 to 50 dynes/cm (Kong, 2004). Creosote or tar oil, as a complex mixture, will generally have a lower IFT (20 to 30 dynes/cm) than a pure chemical product, such as TCE (40 to 50 dynes/cm). IFT determined for the DNAPL at the MW-16 area, as measured with groundwater, was 14.2 dynes/centimeter (HAI, 2005a), which is on the low end with regard to what may be expected for a creosote-type oil. As with wettability, IFT provides an indication of anticipated NAPL entrapment in a porous media, with lower IFT resulting in less entrapment (i.e., lower residual saturation levels) (Kong, 2004).

9.1.2 Chemical Characteristics

Analytical testing of the DNAPL recovered from well WS-11-125 at the northern portion of Siltronic was conducted in 2004, with results summarized in Tables 4 through 6. Results of this testing indicate the DNAPL at this location has a specific gravity of 1.1 is primarily composed of diesel-range hydrocarbons [(593,000 parts per million (ppm)], and contains a high fraction of polynuclear aromatic hydrocarbons (PAHs), with naphthalene having the highest concentration (68,000 ppm). Additionally, carbazole (1,340 ppm), dibenzofuran (858 ppm), and TCE (59.6 ppm) were identified in the DNAPL, as was 271 ppm benzene (MFA,b, 2004). Carbazole and dibenzofuran are semi-volatile organic compounds, that along with PAHs and benzene may be associated with MGP wastes. The TCE is apparently present as a function of the commingling of the heavy oil occurrence with the Siltronic TCE occurrence. TCE, a dense solvent, may be expected to entrain or otherwise increase dissolution and mobility of DNAPL in areas where commingling occurs.

As summarized on Table 5, the overall PAH content of the DNAPL samples from all wells was relatively similar, with the identified total PAH content of the DNAPL found to range from approximately 16.5% at the well MW-11-32 location, to approximately 21.5% at the MW-6-32 well location. The primary distinction among the DNAPL samples with regard to PAH content was the high naphthalene content in the samples from well WS-11-125 (68,000 ppm) and MW-6-32 (31,300 ppm) relative to wells MW-10-25, MW-11-32, MW-16-45 (13,300 ppm to 15,600 ppm). With regard to the ratio of naphthalene to total PAH content, as depicted in Figure 11, naphthalene comprises a much larger percentage of the total PAH content at the MW-16-45 (47%) and WS-11-125 (51 percent) locations, than it does at the other locations (between 7% and 15%), suggesting differential weathering or differing composition of source material.

With regard to monoaromatic hydrocarbons, the highest benzene concentration was identified in the DNAPL sample collected from well MW-10-25 (14,400 ppm), while significantly lower concentrations were identified at well MW-11-32 (2,740 ppm), WS-10-27 (874 ppm), WS-11-125 (271 ppm), MW-6-32 (589 ppm), and MW-16-45 (less than 10 ppm). It is also noted that the DNAPL at the MW-10-25 has a low flashpoint (94°F), which is likely a function of the greater fraction of lighter end compounds at this location. The DNAPL at the MW-10-25 location was also more acidic than measured at other locations with a pH of 4.3.

The varying properties of the DNAPL may be indicative of either differing source locations or of differing release eras related to evolving MGP operations. For example, and with regard to location, the higher benzene concentration identified in oil at the MW-10-25 location is likely a function of a source associated with the former light oil purification plant, where refining of motor fuels, including benzene, was conducted. The light oil plant area was located approximately 200 feet hydraulically upgradient, and up-dip (relative to the slope of the silt unit) of the MW-10-25 well location. Further, and with regard to timing, it is possible that the lack of benzene and the identified high proportion of naphthalene in the DNAPL sample collected from MW-16-45, located immediately beneath the silt unit in the former effluent discharge area (1913 to 1941), may be a function of differing quality of wastes discharged to this area (1913 through 1941) versus the quality of discharges that may have occurred at later dates as increased byproduct recovery occurred.

9.2 DNAPL Distribution

As described previously, DNAPL will occur in the subsurface as either a free-phase or residual liquid. Residual DNAPL is immobile, while free-phase DNAPL may be either mobile or immobile. Immobile free-phase DNAPL may occur as a function of the presence of a stratigraphic trap that the DNAPL has insufficient pressure to penetrate.

DNAPL, both as residual immobile product, and in more limited areas, as free-phase liquid (as identified by accumulation within monitoring wells), has been identified at numerous locations at both the Gasco and Siltronic properties.

A description of locations at the Gasco and Siltronic properties where visual occurrence of DNAPL has been noted on subsurface boring logs is included in Tables 2 (Gasco property) and 3 (Siltronic Property), and is depicted on cross-sections included within Appendix A. The cross-sections distinguish between areas of soil that visually appear “saturated” with DNAPL, based on boring log descriptions, and areas where DNAPL was characterized as patchy or of otherwise limited nature. Similarly, cross-sections depict zones of patchy or mixed soil and solid tar, as well as more limited areas of bulk (non-mixed) solid tar.

Figures 8 through 10 depict the estimated extent of DNAPL based on boring log descriptions, interpretation between boring locations, and descriptions provided by site personnel. As depicted on these figures, all DNAPL has been interpreted as being either: 1) potentially mobile free-phase DNAPL; 2) stratigraphically trapped (non-mobile) free-phase DNAPL; or 3) residual (non-mobile) DNAPL.

9.2.1 *Gasco Property*

Petroleum-related DNAPL (oil) and solid to semi-solid tar are present in the subsurface at the Gasco site, with DNAPL present both within the surficial fill WBZ, and in more isolated areas, within the underlying alluvial WBZ. Tar is limited to the surficial fill unit and the upper portions of the underlying silt unit. As described previously, tar is solid to semi-solid, it is not mobile, and it is not a DNAPL. Viscous oily patches have been observed sporadically within tarry zones at the Gasco site, but such occurrences have been limited. Also, liquid oil fractions that may have been co-placed or discharged with the tar or may have separated from the tar prior to cooling and solidification, are observed present beneath zones with substantial tar placement, with the oil having migrated vertically while the tar remained in-place. A general description of DNAPL occurrence across the Gasco property is provided below.

9.2.1.1 Former Process Areas

As identified in Figure 8, the primary zone of DNAPL occurrence within the surficial fill unit at the Gasco property exists over 400 feet from the river across the southern/southwestern portion of the site, corresponding to the former MGP and Koppers process areas (existing KI coal tar pitch operation area and a portion of the existing NW Natural LNG plant area), including the former Light Oil Plant and Koppers Tank Farm; the former Retort Area; and the former Coke Oven / Koppers Land Disposal Area.

Individual historic sources for the DNAPL occurrence beneath the former processing areas of the property are difficult to interpret due to the distribution of the DNAPL. However, the depth to DNAPL at the site is shallowest in the immediate vicinity of the former Light Oil Plant and Koppers Tank Farm, where DNAPL has been identified at depths as shallow as 2.5 feet (B-22) to 3 feet bgs (B-19) (Table 2), indicating that surface or near surface petroleum releases within and surrounding the tank farm area have occurred. Furthermore, DNAPL has been found to occur at relatively shallow depths at surrounding process area locations. For example, DNAPL has been found to occur at a depth of 7.5 feet bgs at the former Retort Area (B-13); 9.5 feet to 11 feet bgs at the former Coke Oven / Koppers Land Disposal Area (MW-14-110/MW-11-32); and at depths ranging from 7 to 10 feet bgs at the location of the former pitch pans in the central KI Lease area (borings G-1, G-2, B-25, and M-15). Further down-dip from these areas, DNAPL occurrence is between 15 to 28 feet bgs (MW-10-26, MW-6-32).

Sources for the DNAPL in the preceding areas may be from surficial releases associated with former MGP processes, especially near the tank farm/railroad sidings and/or as releases from shallow underground piping that would have likely been present throughout the process area.

As depicted on Figure 8, the presence of patchy DNAPL occurrence at the extreme southern end of the KI Lease Area (B-24 and MW-12-36), suggests that DNAPL south/southeast of the KI tank farm is present in residual (non-mobile) form. Further, no DNAPL was identified immediately northwest of the tank farm (B-18 and B-21) or below much of the western LNG plant area (B-14 and MW-9-29) indicating an absence of DNAPL release within, or migration beneath, these areas. Otherwise, examination of soil boring descriptions indicate soils to be visually saturated with DNAPL at certain depth intervals across much of the area proximate to, and extending north/northeast (down-dip relative to the underlying silt unit) of the KI tank farm. Although not conclusive by itself, the visual indication of DNAPL-saturated soils suggest that the DNAPL beneath this area may be free-phase, with the occurrence of DNAPL entry into surficial fill WBZ wells (MW-6-32, MW-10-32, and MW-11-32) within and down-dip of the former process areas confirming that free-phase DNAPL does exist within at least portions of the area.

Although free-phase DNAPL is present, the nature of the underlying silt unit has acted as an effective barrier to both lateral and vertical movement from former process area sources, as described below.

As depicted on Figure 5, the silt unit beneath the process area is relatively shallow and dips steeply towards the central portion of the site to a linear trough feature that tends to parallel the river. As previously described (HAI, 2005b), this feature is likely a former creek channel that traversed the property prior to development. The distribution of DNAPL down-dip of the process area indicates that this trough-like feature in the surface of the silt unit has acted to stop the lateral migration of DNAPL from the current KI and LNG Plant areas to the northeast towards the Willamette River (Figure 8).

The preceding is supported by the observed presence of free-phase DNAPL within wells located in low points within the depression (MW-6-32 and MW-11-32), or on the up-dip slope of the silt surface closer to primary source areas (MW-10-26), while no DNAPL has been identified on the opposite (riverward) side of the depression (borings B-7, B-10, B-47, and MW-13-30), or in more northerly areas of the depression (B-4 and B-5).

In addition to preventing the lateral movement of free-phase DNAPL from former MGP and Koppers process areas towards the river, the silt unit has also prevented the vertical movement of DNAPL across a majority of the Gasco site. Due to the chemical composition of the DNAPL, and as observed beneath the former tar effluent pond area, DNAPL migration into the alluvial WBZ will produce a significant dissolved phase contaminant plume (e.g., benzene and naphthalene). No visual evidence of product migration to the alluvial WBZ has been identified beneath the former process areas, and more conclusively, no significant dissolved phase impacts have been identified within the alluvial WBZ beneath or immediately down-gradient of former process areas (e.g., monitoring wells MW-2-61, MW-10-61, MW-13-61, MW-14-110, and MW-15-65).

In summary, the presence of DNAPL within surficial fill monitoring wells down-dip of the process area, in conjunction with the visual indication of DNAPL saturated soils from boring logs, indicate the presence of free-phase DNAPL within the fill across various depth horizons beneath the former MGP process areas (much of the KI Lease Area and a portion of the NW Natural LNG plant). However, the free-phase DNAPL is stratigraphically trapped (immobilized) by the underlying silt unit throughout this entire area. Based on the preceding, DNAPL migration to the Willamette River from former process areas at the Gasco site is not currently occurring, nor does it appear to be a reasonably likely future occurrence.

9.2.1.2 Former Tar Effluent Pond and Effluent Discharge Areas

Soils mixed with solid to semi-solid tar (not a DNAPL) are present above the silt unit throughout the eastern corner of the site, corresponding to the location of the former tar effluent pond area and the former effluent discharge area (Figure 3). Both of these areas are waste management related, as opposed to process related, where tar and oil were discharged to the former ground surface (top of the silt unit), and where tar has been incorporated into shallow fill. Little to no DNAPL has been identified in the surficial fill across these portions of the property (Figure 8). Instead, solid tar and tarry soils are present across these areas. Field screening/observation of soils at these areas indicate that DNAPL typically occurs beneath the fill, within thin rootlets in the native silt, and in more limited areas, extending into the upper alluvial WBZ (Figure 9).

With specific regard to DNAPL penetration into the alluvial WBZ (Figure 9), DNAPL has been observed within soils beneath the alluvial silt unit at the Gasco site only in the former tar effluent pond area (e.g., borings B-32, B-33, B-35, and MW-8) and in the former effluent discharge area (e.g., borings B-55 through B-59, B-29 and MW-16-45) (HAI 2005b). DNAPL at the former effluent discharge area has been observed within the upper alluvial WBZ to a depth of approximately 42 to 44 feet bgs, while DNAPL beneath the former tar pond area has been observed in soils as stringers and blebs within the silt unit and upper alluvial WBZ to a depth of up to 67 feet bgs (B-33).

Because both waste management areas were filled subsequent to cessation of MGP operations, oily effluent discharge to fill soils in these areas did not occur and no significant zones of DNAPL presence have been identified in surficial fill above the silt unit (e.g., the former ground surface). Although, as described above, DNAPL has been identified beneath the silt unit in these areas, monitoring wells screened within the mid- to lower-alluvial WBZ throughout the area (e.g., MW-4-101, MW-5-175, and MW-16-125 at Gasco, and WS-15-140 and WS-16-161 at Siltronic) have confirmed a lack of dissolved phase impact, thereby defining the vertical extent of impact at all locations (HAI, 2005a,b).

<u>Former Tar Effluent Pond Area</u>

Based on observations made during the installation of borings within the former tar effluent pond area, it appears the DNAPL at this portion of the site is likely a result of the combination of direct discharge of oil and oil/water emulsions to the former ground surface (silt unit), as well as liquid oil fractions that may have separated from the tar prior to cooling/solidification. Boring logs indicate the presence of solid hardened tar above the silt, underlain by millimeter thin rootlet casts within the underlying silt unit containing viscous black oil that in turn transitions to a visually less viscous brown oil at depth. The oil fractions had the ability to migrate through these rootlet features, while the tar remained immobilized within the fill. At certain locations (e.g. borings B-32, B-33, B-34, and MW-8), the DNAPL has been observed to extend within the rootlets through the silt unit and into the upper portion of the underlying alluvial WBZ, resulting in a well defined dissolved phase plume of petroleum contamination (e.g., benzene and naphthalene) within the upper to mid-depth intervals of the alluvial WBZ.

As noted on boring logs B-32, B-33, and MW-8-56, DNAPL is visually saturating sandier intervals within the upper alluvial WBZ beneath portions of the former tar pond area, suggesting the presence of free-phase DNAPL in these areas. After 10 years of monitoring, no DNAPL has entered alluvial WBZ well MW-8-56 installed immediately north of the former tar effluent pond area, suggesting that DNAPL at this area may be residual. However, DNAPL has been identified within alluvial WBZ wells proximate to the former tar pond area, both on the Siltronic property (described in Section 9.2.2), and at one location between the former tar effluent pond and the river on the Gasco property (PW-01-80), confirming the presence of free phase DNAPL within the Alluvial WBZ in the tar effluent pond vicinity.

With regard to Gasco, a thin zone of brown DNAPL was identified within soils across a depth interval of approximately 58 to 59 feet bgs during the construction of well PW-01-80 (cross-section D-D', Appendix A), a well screened from 40 to 80 feet bgs within the alluvial WBZ approximately 200 feet down-gradient of the former tar effluent ponds. Subsequent to development, approximately 2-inches of DNAPL were measured within the sump at the base of this well. This well, installed as a pumping well for completion of an aquifer test (see HAI, 2005d), is located approximately 25 feet upland of the monitoring well MW-4 cluster and is screened across the central portion of a dissolved phase benzene plume, as previously described (HAI, 2005a) adjacent to the river at the MW-4-56 alluvial WBZ monitoring well location.

The specific source for the DNAPL identified at the PW-01-80 well, based on location, depth, and lack of immediately overlying DNAPL, may be attributable to migration of DNAPL from identified sources within the alluvial

WBZ beneath the former tar effluent ponds. However, the zone of potential migration appears very limited since no DNAPL has been observed at nearby monitoring wells, including upriver locations MW-17-79 (70 feet away) or downriver shoreline location MW-16-65 or MW-16-125 (190 feet away). Further, no DNAPL was identified at depth during installation of the MW-4 well cluster, located approximately 25 feet riverward of PW-1-80.

In summary, the presence of a thin zone of DNAPL entering the PW-1-80 borehole indicates that the DNAPL at this location is free-phase. Collection of additional in-water data is proposed to determine whether dissolved phase impact from this DNAPL location is migrating to the Willamette River.

Former Effluent Discharge Area

With regard to the former effluent discharge area, a soil matrix including tar (primarily black, patchy, solid to semi-solid) was identified within fill at depths ranging from 1 to 2 feet bgs and extending to depths ranging from approximately 22 to 30 feet bgs at all boring locations except B-53 and B-54 (near the river embankment), where only very minor patchy tar or tar flecks were identified within the fill. Visually-impacted zones containing DNAPL were identified across depth intervals of 27.5 to 32 feet bgs at boring B-55; 26.5 to 37.5 feet bgs at boring B-57; 22.25 feet bgs (thin zone) and 30.5 to 37 feet bgs at boring B-58; and 30 to 38 feet bgs at boring B-59 (HAI, 2005a). Interruption of vertical DNAPL migration was observed across this area, with apparent pooling of likely free-phase DNAPL occurring above thin silt layers that were prevalent throughout the upper alluvial WBZ (HAI, 2005a).

The installation of the MW-16 series monitoring well cluster in this area indicated brown oil coating soils from 27.5 feet bgs to 44 feet bgs (upper alluvial WBZ), with no oil identified at depth below 44 feet bgs. Subsequent to completion of the MW-16 monitoring wells, DNAPL has collected in the bottom of the upper alluvial WBZ well MW-16-45. DNAPL thicknesses of up to 6 feet have been observed in monitoring well MW-16-45. No DNAPL has been identified in the intermediate-depth well MW-16-65 or in the deep well MW-16-125, screened within the alluvial WBZ at this location. The lateral and vertical extent of dissolved phase groundwater contamination has been defined at this location.

Mobility screening results (HAI, 2005a) indicate that DNAPL is likely present at levels greater than residual saturation at depths between 29 feet bgs and 42 feet bgs at the MW-16 well location. Oil present in cores recovered from the MW-16 location were at saturations greater than 50% which is above typical residual saturation levels (5 to 50%). In addition, the DNAPL mobility screening results indicate that the oil at this location has relatively low interfacial tension and neutral wettability, which along with the elevated saturation levels indicate that the oil has a relatively high mobility potential. Although the potential for ongoing mobility is present, previous investigations, including in-water sediment borings, indicate that a laterally thickening wedge of silt present between the upland portion of the site and the river is acting as a barrier to the transport of DNAPL, with no complete physical subsurface pathway between the zone of DNAPL below the upland portion of the site and river sediments in this area (cross-sections B-B' and C-C', Appendix A).

Although no connection between the DNAPL at the MW-16 area and the river has been identified, as a precaution due to its horizontal and vertical proximity to the river, a technology and alternatives screening for a focused feasibility study has been prepared for the development of a DNAPL-related source control action in this area, which has been submitted to the DEQ (HAI, 2005c). The objective of source control activities in this area is to minimize the potential for future DNAPL migration to the river.

9.2.1.3 Former Spent Oxide Storage Area

DNAPL has been identified within the surficial fill unit in proximity to the former spent oxide storage area at the MW-1 and B-1 boring locations at the northern portion of the Gasco site (Figure 8). The zone of oil saturation was found to consist of an interval located immediately above the silt unit at depths ranging from 16 to 21 feet bgs. Boring logs indicate that much debris had been deposited at this portion of the site as fill, including concrete, bricks and solid carbon pitch. As borings B-2, B-3, B-4, B-5, and B-7 do not show indications of DNAPL, and are located between the area of observed oil and the primary oil source areas at the southwestern portion of the site (e.g., former light oil plant / retort area), it appears that the identified DNAPL was likely mixed into fill at this portion of the site as a component of the fill, and its presence is not a result of migration from other areas. With regard to the potential mobility of the observed product, it is noted that well MW-1-22 is screened directly across the zone of observed DNAPL saturation, and that no DNAPL has entered this well (after 10 years of monitoring). Based on the preceding, it appears that the observed DNAPL at this portion of the site is likely in the form of residual product and is therefore not mobile.

9.2.1.4 FAMM Above-Ground Storage Tank Area

As indicated on the lithological log for geotechnical boring GT-1, a boring installed within the north end of the southern FAMM tank farm, a zone of NAPL was found to occur from a depth of 8.5 to 11 feet bgs (Figure 8). The identified product had a diesel odor uncharacteristic of the oil encountered at the rest of the site. Analysis of a soil sample from the zone of product saturation indicated total petroleum hydrocarbons within the diesel range of 13,400 ppm, with no carcinogenic PAHs identified. The preceding, as well as the location of the product being within the FAMM tank farm, an area where petroleum products are actively managed, indicates the source of the oil is likely related to post MGP-related tank farm operations. The extent of the apparent diesel product in the subsurface appears limited, as no such product was identified at adjacent boring locations B-8, B-52, or GT-2.

9.2.2 Siltronic Property

Similar to the Gasco property, petroleum-related DNAPL (oil) and solid to semi-solid tar are present in the subsurface at the Siltronic site, with DNAPL present both within the surficial fill WBZ, and in a more isolated area (extreme northern portion of the property), within the underlying alluvial WBZ. As described previously, tar is solid to semi-solid, it is not mobile, and it is not a DNAPL. Viscous oily patches have been observed sporadically within tarry zones, but such occurrences have been limited. Liquid oil fractions that may have been co-placed or discharged with the tar, or that may have separated from the tar prior to cooling/solidification, are observed beneath areas where substantial tar and oily effluent discharge occurred, with the oil having migrated vertically while the tar remained in-place. The following Sections describe the distribution of DNAPL (or NAPL in cases where density is unknown) at the Siltronic property.

9.2.2.1 Former MGP Waste Management Areas

As described in Section 5.2.2, potential DNAPL-related waste management activities at the Siltronic property were limited to the northern, approximate 400-foot wide former lowland area and an adjacent excavated area/depression. These areas were located on the northern and western portion of the Siltronic property, areas nearest to the adjacent Gasco property (Figure 3).

With regard to the presence of DNAPL in the surficial fill at the Siltronic property, DNAPL (oil) has been identified within one surficial fill WBZ monitoring well, located at the north central portion of the Siltronic site (WS-10-27). This well is located approximately 900 feet upland from the Willamette River shoreline at the southeastern edge of the former 400-foot wide lowland area. The thickness of DNAPL accumulation in this well ranges between approximately 1 to 2 feet, with oily zones at this location identified within the soil column between approximately 21 to 27 feet bgs. Subsurface conditions at WS-10-27 appear similar to those identified to the northwest across the Gasco/Siltronic property line, with the silt unit being quite thick; little to no DNAPL penetration into the silt unit; and no DNAPL identified beneath the silt unit (cross-sections G-G’ and J-J’, Appendix A).

The DNAPL observed at the WS-10-27 location may be attributable to overflow or placement of MGP byproducts from the former Gasco effluent ponds into the former lowland area at Siltronic (Section 5.2.2). With regard to lateral extent, borings installed surrounding the WS-10-27 location to the northeast, north, west, and south either indicate no DNAPL (GP-18, GP-20, GP-21, GP-23, GP-24, B-100) or patchy/limited (possibly residual) DNAPL (B-SU-8, B-24). Based on the preceding, with some uncertainty to the immediate west and to the east-southeast of WS-10-27 below the Fab 2 structure, the extent of free-phase DNAPL proximate to the WS-10-27 area appears limited. Further, as depicted on cross-sections G-G’ and J-J’ (Appendix A), the free-phase DNAPL at this area is stratigraphically trapped and would not have a complete pathway to the Willamette River.

With regard to vertical DNAPL penetration through the silt unit and into the alluvial WBZ (Figure 9), DNAPL has been observed at the Siltronic site within soils collected from beneath the silt unit at borings B-1-8, B-2-8, WS-11, WS-14, WS-15, and WS-16 (Table 3). All of the preceding locations are in the extreme northern portion of the former 400-foot wide lowland area, below, and proximate to, the western end of the Fab 1 building. As depicted on Figure 9, this area appears contiguous with the presence of deep DNAPL penetration to the east and southeast beneath the former tar effluent ponds at the adjacent Gasco property. DNAPL migration through the silt unit in this area is likely a function of the large volume of oily effluent placed in / discharged to the northwestern portion of the Siltronic lowland area (WS-15, WS-16, and B-1-8) / eastern portion of the Gasco effluent tar pond area (B-32 and B-33), where sufficient volume and entry pressure for DNAPL penetration of the silt unit (via dispersed rootlet casts) existed.

The deepest NAPL directly observed within soils beneath the former lowland area on the Siltronic property has been identified in borings B-1-8 and WS-16, with DNAPL logged to depths of up to 74 feet bgs (WS-16), at which point vertical migration was interrupted by a silt layer within the upper alluvial WBZ (cross-section E-E' and I-I', Appendix A). In addition, DNAPL has been identified at the WS-15-85 location (central portion of the former lowland area screened from 70 to 85 feet bgs) where up to 6 feet of DNAPL have accumulated within this well (cross-sections F-F' and I-I', Appendix A). As depicted on cross-section I-I', it is possible that the DNAPL at this location may have migrated laterally to this area down-dip along one or more silt layers that may extend beneath the effluent tar pond and the overflow area (cross-section I-I'). Alternatively, or additionally, the DNAPL may have migrated down-dip along a silt layer or layers from a more northern portion of the former 400-foot wide overflow area (cross-section F-F') proximate to the western end of the Fab 1 Building.

In addition to the identification of DNAPL within the upper alluvial WBZ beneath a portion of the former effluent tar pond (Gasco) and the adjacent former lowland area (Siltronic), DNAPL has also been identified at the northern corner of the Siltronic property at nearshore well locations WS-11-125 and WS-14-125, where 0.5 to 3 feet of oil have been identified at the base of these wells (cross-sections A-A', E-E', and F-F'). Based on the screened intervals for these wells, the DNAPL at these locations has entered the wells from some interval between 110 and 125 feet bgs, which is well below the base of the adjacent Willamette River. Figure 10 depicts the estimated extent of deep DNAPL (i.e., greater than 100 feet bgs) in the alluvial WBZ. Cross-sections A-A', E-E', and F-F' depict the location of the DNAPL relative to the base of the river.

The DNAPL identified within the alluvial WBZ in proximity to the river at the WS-11-125 and WS-14-125 locations would appear to be the result of vertical migration of DNAPL beneath the former Gasco tar effluent ponds / northern Siltronic lowland area, with lateral migration occurring above finer-grained horizons that provide the necessary capillary resistance to vertical movement. The deeper penetration of DNAPL at the Siltronic property relative to the Gasco property (Figures 9 and 10) corresponds with the greater depth of dissolved phase groundwater impacts down-gradient of the former lowland area (HAI, 2005b), which have been well delineated across the upland area (HAI, 2005b).

Observation of soil conditions, as well as the resulting groundwater plume distribution, suggests deep penetration of DNAPL may have occurred in proximity to the Gasco/Siltronic property boundary (B-32 and B-33) and/or in the WS-16/B-1-8 area at the Siltronic property. Further, the significantly deeper DNAPL and resulting dissolved phase plume identified at the northern portion of Siltronic may be a function of commingling with the Siltronic TCE plume, which as a dense solvent, for which petroleum is miscible, may promote deeper transport of the less dense petroleum.

Both the lateral and vertical extent of the deep DNAPL have been well delineated, with surroundings boring locations (e.g., MW-5, MW-17, WS-12, and WS-16 locations) providing good control, both with regard to direct soil observation, and with regard to dissolved phase contaminant levels. Although present as a free-phase DNAPL, the depth of the DNAPL relative to the adjacent river (i.e., well below the base of the river) does not suggest the potential for migration concerns with regard to the river.

9.2.2.2 Other Areas of the Property

With regard to other shoreline area borings at the Siltronic site, borings P-4, P-5, P-7, and B-HQ-8 identified the presence of thin (0.5 to 4 feet thick) zones of weathered tar or oil within the fill (Figure 8). Oily soils identified at the P-4, P-5, and P-7, and B-HQ-8 locations appear to be mixed with fill and would not appear attributable to former MGP waste management areas. These occurrences, as well as areas further upland, are discussed below.

Oily soil identified at the P-7 location correlates with the area of possible discolored soils, as identified in 1970 aerial photograph of the site, as being present in the immediate vicinity of the former Western Transportation structures (Figure 3). The low concentrations of PAHs in the oily soil identified at P-7 (total PAHs are less than 2 percent of the TPH), as well as its location relative to the suspected historical surface staining, suggest that the impacts at this location are likely diesel or fuel oil related, and appear to be associated with the former Western Transportation fueling operations or possible dismantling related to their operations (HAI, 2005b). Western transportation had ownership of the parcel from between 1943 to 1968. The observed oil at this location was patchy and likely residual.

Further upland at the B-HQ-8 location, oil was noted at a depth of 10 feet bgs (fill) and did not extend over a notable interval of soil, and as such would likely be of very limited extent. At the P-5 boring location, the oily zone correlated with the presence of brick fragments also appears very limited (not observed at adjacent well WS-9-34). With regard to the P-4 location, the identified NAPL was present within the fill across an interval of between 20 to 24 feet bgs and did not appear to be saturating the soils. The identified NAPL zone was found isolated well above the pre-fill ground surface and therefore did not appear to have been discharged to this area prior to filling. Further, Siltronic's recent installation of boring GP-33 at the location of boring GP-4 (MFA, 2005) did not replicate the identification of NAPL, suggesting the NAPL at P-4 was mixed into fill and is very limited in extent. Based on these observations, it appears that the oil identified at the preceding locations is a function of incorporation of oil and tar into the fill during placement (1966-1975), as opposed to active MGP activities at the site.

In addition to the preceding, as depicted on Figure 8 and cross-sections K-K' and L-L', Appendix A), NAPL has been identified within the surficial fill unit near the undeveloped southern corner of the Siltronic property, with observations on boring logs of oily soils identified below a depth of 10 feet bgs, with the thickness of oily zones ranging from 1 foot or less (WS-6, B-6, B-102), to up to 10 feet (WS-1, WS-2). Although some of the NAPL identified in this area appears to be saturating the soils (i.e., potentially free-phase), monitoring wells installed in this area, screened across the oily zones, have not identified the presence of NAPL accumulation, suggesting that NAPL in this area is in residual form. Boring log evaluation as well as groundwater quality within the alluvial WBZ across and down-gradient from these portions of the property (cross-sections A-A', K-K', and L-L') do not suggest the occurrence of DNAPL penetration into the alluvial WBZ at any of these areas. Due to a lack of MGP-related process or waste management activities at this area, and the isolation of this area relative to impacts further northwest (e.g., no NAPL at the B-100, B-101, B-103, or WS-4 locations), it appears these NAPL zones would be attributable to filling from 1966-1975 as opposed to MGP-related waste management activities.

9.3 Relationship Between Upland DNAPL and River Sediments

With regard to Willamette River sediments, aerial photographs and site history clearly indicate that substantial direct deposition to offshore sediments of oil gasification by-products occurred for a number of years early in the 20th century. From 1913 to 1925, wastewaters and tars not usable as fuel would have been discharged to drainage features leading from the production area to the Willamette River. Prior to 1941, waste by-products from the oil gasification process that did not have a market (wastewater with petroleum emulsions and tars) would have continued to have been discharged to low-lying areas of the site and drainage features leading from the production area to the Willamette River. Subsequent to 1941 and until plant closure in 1956, these wastes would have overflowed to the low area on the northern portion of the Siltronic property or may have been excavated from ponds on the Gasco property and placed in this low area. The low area may have drained to the river approximately 400 feet upriver from the current Gasco/Siltronic property boundary (HAI, 2005b).

Waste by-products include both relatively oily and tarry substances that may also have become substantially weathered in the river environment over the years. Consequently, these substances are found in deposits such as the “tar body” (which has recently been removed by NW Natural under a separate EPA consent order) and in sediment core profiles in the nearshore sediments. With regard to upland migration of DNAPL, direct discharges such as seeps of DNAPL or movement of tar in soils to the sediments have not been observed at either the Gasco or Siltronic properties.

As previously described, free-phase DNAPL has been identified within monitoring wells at two nearshore upland locations near the eastern corner of the Gasco property (MW-16-45 and PW-01-80) and two shoreline locations at the extreme northern corner of the Siltronic property (WS-11-125 and WS-14-125). The DNAPL present in these areas is attributed to historic discharge of MGP waste by-products to the former effluent discharge area between 1913 and 1941 (MW-16-45), and to the former effluent tar ponds at Gasco and/or the adjacent former lowland area at Siltronic between 1941 and 1956 (PW-01-80, WS-12-125, WS-14-125). In addition to the preceding, DNAPL, either in residual or free-phase form, has been identified within the surficial fill unit at various portions of the Gasco and Siltronic properties, either as a function of process-related spills (Gasco) or waste management and fill incorporation (Gasco and Siltronic).

An evaluation of these areas of DNAPL occurrence in relationship to observed sediment conditions and/or the potential for future migration to sediments is provided below.

9.3.1 Former Effluent Discharge Area - Gasco

With regard to the MW-16-45 area, although screening of the soils have found the DNAPL in the upper alluvial WBZ in this area to be free-phase and potentially mobile, a laterally thickening prism of silt between the zone of product and the river appears to have acted as a barrier to the lateral migration of oil. Further, deep sediment cores collected as part of off-shore “tar body” removal investigation and design (Anchor, 2005), found no evidence for physical connection between the upland DNAPL area and the tar body.

Although free-phase DNAPL at the former effluent discharge area has not been identified extending to adjacent sediments, as a precaution due to its horizontal and vertical proximity to the river, a technology and alternatives screening for a focused feasibility study has been prepared for the development of a DNAPL-related source control action in this area, which has been submitted to the DEQ (HAI, 2005c). The objective of source control activities in this area is to minimize the potential for future DNAPL migration to the river.

9.3.2 Former Tar Effluent Pond Area - Gasco

The DNAPL identified between the tar effluent pond and the river at the PW-01-80 location was found to occur within the upper- to mid-depth alluvial WBZ in a thin zone extending across a depth interval of approximately 58 to 59 feet bgs, corresponding to a zone of significantly elevated benzene concentrations in alluvial WBZ groundwater. The source for this DNAPL would appear to be the result of vertical migration beneath the former tar effluent pond area, with lateral gravity-driven transport likely occurring toward the river above a finer-grained horizon within the subsurface.

Based on the entry of the DNAPL into the PW-01-80 well, it would appear that DNAPL at this location is potentially mobile, albeit across a very thin and limited interval (nearby upland locations did not identify the presence of DNAPL across similar depth intervals). Additional investigatory activities are warranted with regard to the properties of the DNAPL identified at PW-01-80, and the off-shore evaluation of lithology, groundwater quality to ascertain the potential for migration of DNAPL related dissolved impacts from this upland location to river sediments. Further, two additional borings between the PW-01-80 location and the former tar effluent pond area may assist in determining the overall source location (e.g., northwest or southeast pond area) for the DNAPL observed at this well.

9.3.3 Former 400-Foot Wide Lowland Area - Siltronic

DNAPL identified at depth in proximity to the river at the at the WS-11-125 and WS-14-125 well locations appear to be the result of vertical migration of DNAPL beneath the extreme northern portion of the former Siltronic lowland area and/or the southeastern portion of the adjacent Gasco effluent tar ponds, with lateral migration above finer-grained horizons within the alluvial WBZ. The DNAPL identified adjacent to the shoreline, although apparently free-phase, is present at a depth well below the base of the river. The significantly deep DNAPL penetration and the resulting deep dissolved phase plume identified at the northern portion of the Siltronic property may be a function of commingling with the Siltronic TCE plume, which as a dense solvent may promote mobilization and deeper transport of the less dense petroleum. Both the lateral and vertical extent of the deep DNAPL occurrence have been well delineated based on direct observation of soils, as well as the defined distribution of dissolved phase impacts.

With regard to off-shore conditions, a significant number of borings have been installed off-shore of the WS-11-125 and WS-14-125 location by MFA as part of TCE investigation (MFA, 2004a). Direct observation of upland and in-water soil core indicate the upland DNAPL to be wholly disconnected and separate relative to the shallow oily sediments identified at off-shore locations. Specifically, borings installed offshore of WS-11 and WS-14 through the entire thickness of the alluvial unit did not identify the presence of upland-area DNAPL across horizons that would be indicative of subsurface transport (oil was limited to near surface shallow sediments which would appear to have been directly placed as a result of historical discharge). Further, due to the depth of the DNAPL (greater than 100 feet bgs); the density of the DNAPL (greater than 1.0); and the apparent presence of a downward hydraulic gradient beneath the river, the DNAPL identified at the upland nearshore locations does not appear to be a future migration threat with regard to the river (e.g., it would need to migrate upwards against gravity and the predominant vertical gradient in order to intercept the river).

Based on the preceding, source control activities at the Siltronic property designed to mitigate DNAPL migration to the Willamette River do not appear warranted at this time. However, to provide additional data to more clearly understand the origin of the deep DNAPL occurrence, physical/chemical characterization of DNAPL at WS-11-125, WS-14-125, and at the upland WS-15-85 location should be conducted. Further, characterization of subsurface conditions (lithology, DNAPL occurrence and saturation levels), should be conducted as close to the B-1-8 location (a possible source for the deeper DNAPL) as feasible in order to determine if the shallow DNAPL previously identified in the surficial fill at this location is accurately portrayed, and if so, whether this area is a possible source for deeper DNAPL occurrences.

9.3.4 Surficial Fill DNAPL Occurrence – Gasco and Siltronic

Free-phase DNAPL has been identified in uplands soils well away from the Willamette River beneath and/or down-dip of the former MGP process areas at Gasco (MW-6-32, MW-10-25, and MW-11-32) and in a more limited area within a portion of the former 400-foot wide lowland area at Siltronic (WS-10-27). The silt unit is very thick throughout this area, with little to no DNAPL penetration into the silt unit. No DNAPL has been observed beneath the silt unit at any location across the MGP process areas or the overflow area proximate to well WS-10-27. Further, no related dissolved phase impacts have been identified within groundwater beneath or immediately down-gradient of these areas, confirming the lack of vertical DNAPL migration at these areas. A rise in the slope of the silt unit surface between those upland areas with DNAPL occurrence and the shoreline appears to have prevented lateral migration. As such, shallow zones of DNAPL present beneath the former MGP process areas and near the north/central portion of Siltronic (WS-10-27) appear stratigraphically trapped (immobilized) by the underlying silt unit throughout entire area and do not have a complete pathway to the Willamette River.

In addition to the preceding, NAPL has been identified within surficial fill at limited areas of Gasco (e.g., former spent oxide area and FAMM) and Siltronic (imported contaminated fill or redistribution of soils from the lowland area into surficial fill). As described in Section 9.2, NAPL within these areas appear to likely be non-mobile residual, and source control activities designed to mitigate NAPL migration to the Willamette River from these areas do not appear warranted.

10.0 SUPPLEMENTAL DNAPL-RELATED DATA NEEDS

Based on the description and evaluation of DNAPL occurrence at the Gasco and Siltronic properties as described herein, the following supplemental data needs have been identified.

- A thin zone of DNAPL was identified across a depth of 58 to 59 feet bgs at the PW-01-80 location. A sample of this DNAPL should be collected, if possible, for chemical and physical property evaluation such general DNAPL properties may be more completely understood and so that common or unique attributes relative to DNAPL at other locations may be evaluated. Additionally, offshore investigatory activities should focus on the area offshore of the PW-01-80 well location such that subsurface lithology can be determined and correlation of the upland DNAPL or dissolved impacts to sediment may be made.

- DNAPL present within Siltronic alluvial wells WS-11-125, WS-14-124, and WS-15-85 and surficial fill WBZ well WS-10-27 should be sampled for chemical and physical property analyses such that comparison with DNAPL from other areas may be made and so that general DNAPL properties at these locations may be more completely understood.

- The installation of deep push probe borings at key locations may supplement the understanding of the overall source area within the former lowland area (Siltronic) and/or the former tar effluent pond area for DNAPL identified at the PW-01-80, WS-11-125, and WS-14-125 wells, as follows:

  - One push probe boring at the extreme northern portion of the former Siltronic overflow area near the western end of Fab 1 building, as near to B-1-8 as feasible in order to determine if the shallow DNAPL previously identified in the surficial fill at this geo-technical boring location is accurately portrayed, and if so, whether this area is a possible on-going source for deeper DNAPL occurrences.

- Two deep push probe borings between the former tar effluent ponds and the PW-01-80 location, with one boring installed midway between MW-8-56 and PW-01-80, while the other boring would be installed midway between boring B-32 and PW-01-80. These borings will help determine if transport to the PW-1-80 location occurred from the eastern tar effluent pond area (near Siltronic) or from the western tar effluent pond area (near the former effluent discharge area).

11.0 LIMITATIONS AND SIGNATURES

The information presented in this report was collected, analyzed, and interpreted following the standards of care, skill, and diligence ordinarily provided by a professional in the performance of similar services as of the time the services were performed. This report and the conclusions and/or recommendations contained in it are based solely upon research and/or observations, and physical sampling and analytical activities, if any, that were conducted at the Client's request.

The information presented in this report is based only upon activities witnessed by HAI or its contractors, and/or upon information provided to HAI by the Client and/or its contractors. The analytical data presented in this report, if any, document only the concentrations of the target analytes in the particular sample, and not the property as a whole.

Unless otherwise specified in writing, this report has been prepared solely for the use by the Client and for use only in connection with the evaluation of the subject property. Any other use by the Client or any use by any other person shall be at the user's sole risk, and HAI shall have neither liability nor responsibility with respect to such use.

Hahn and Associates, Inc.

Prepared by:

Robert Ede, R.G.
Sr. Associate

REGISTERED PROFESSIONAL
OREGON
ROBERT B. EDE
G1823
GEOLOGIST

Date Nov. 7, 2005

12.0 REFERENCES

Anchor (2005). Removal Action Project Plan, Final Design Submittal, *Removal Action, NW Natural "Gasco" Site,* Anchor Environmental, L.L.C., July 2005.

Anderson, W.G., 1987, *Wettability Literature Survey – Part 6: Effects of Wettability on Capillary Pressure*, Conoco, Inc., SPE Publications.

Camp Dresser & McKee, Inc., 1987, North Doane's Lake Site Characterization Work Plan, June 1987

Cohen, R.M., and Mercer, J.W., 1993, *DNAPL Site Evaluation*, C.K. Smokey, EPA/600/R-93/022, February 1993.

DEQ, 2005, *Comments on Supplemental Investigation Report, Siltronic Corporation, Portland, Oregon*, Correspondence Mr. Dana Bayuk to Mr. Tom McCue, October 26, 2005.

EPA, 1992, *Estimating Potential Occurrence of DNAPL at Superfund Sites*, Publication 9355.4-07FS, U.S., Environmental Protection Agency, January 1992

Geraghty & Miller, Inc., 1991, *Hydrogeological Investigation of the Doane Lake Area, Portland, Oregon*, February 22, 1991

HAI (2001), *Report on Dense Non-Aqueous Phase Liquid Recovery System Installation; NW Natural-Gasco Facility, 7900 NW St. Helens Road, Portland, Oregon*, Hahn and Associates, Inc., January 8, 2001

HAI (2005a). *Report on Supplemental Upland Remedial Investigation Activities,* Hahn and Associates, Inc., March 11, 2005

HAI (2005b). *Updated Phase I Site Characterization Summary Report, Siltronic Corporation Property, 7200 NW Front Avenue, Portland, Oregon.* Hahn and Associates, Inc., July 22, 2005

HAI (2005c). *Technical Memorandum: DNAPL Focused Feasibility Study, MW-16 Area, NW Natural Gasco Site, Portland, Oregon.* Hahn and Associates, Inc., September 26, 2005

HAI (2005d). *Aquifer Test Evaluation Report, NW Natural – Gasco Facility, 7900 NW St. Helens Road, Portland, Oregon.* Hahn and Associates, Inc., October 14, 2005

Jackson, R, Varadarajan, D., Ewing, J., and Avis, J. (2004). *The Migration of Viscous NAPLs in Alluvium, Implications for Brownfields Re-development and Surface Water Contamination*, INTERA Engineering, Inc., presented at the Canadian Geotechnical Conference, October 2004.

Kong, L. (2004). *Characterization of Mineral Oil, Coal Tar and Soil Properties and Investigation of Mechanisms That Affect Coal Tar Entrapment in and Removal From Porous Media*, Georgia Institute of Technology, July 2004.

MFA (2004a) *Final Remedial Investigation Workplan, Siltronic Corporation Site, 7200 NW Front Avenue, Portland, Oregon.* Maul Foster Alongi, Inc., September 17, 2004

MFA (2004b) *MGP Data Submittal, Siltronic Corporation, 7200 NW Front Avenue, Portland, Oregon.* Maul Foster Alongi, Inc., December 13, 2004

MFA (2005) *Supplemental Investigation Report, Siltronic Corporation Facility, 7200 NW Front Avenue, Portland, Oregon.* Maul Foster Alongi, Inc., September 8, 2005

U.K. Environment Agency (2003) Kueper, B.H., and Weatherall, G.P., *An Illustrated Handbook of DNAPL Transport and Fate in the Subsurface*, R&D Publication 133, June 2003

13.0 GLOSSARY OF ABBREVIATIONS

AST	above ground storage tank
bgs	below existing ground surface
BNSF	Burlington Northern Santa Fe Railroad Company
CDM	Camp Dresser & McKee, Inc.
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
EPA	U.S. Environmental Protection Agency
FAMM	Fuel and Marine Marketing, Inc.
HAI	Hahn and Associates, Inc.
IFT	interfacial tension
KI	Koppers, Inc.
LNAPL	light non-aqueous phase liquid
LNG	liquefied natural gas
MFA	Maul Foster & Alongi, Inc.
MGP	manufactured gas plant
msl	mean sea level
NAPL	non-aqueous phase liquid
PacTerm	Pacific Terminal Services
PAHs	polynuclear aromatic hydrocarbons
PG&C	Portland Gas & Coke
PNO	Pacific Northern Oil
ppm	parts per million
RI	Remedial Investigation
Siltronic	Siltronic Corporation
SVOCs	semi volatile organic compounds
TCE	trichloroethene
WBZ	water-bearing zone